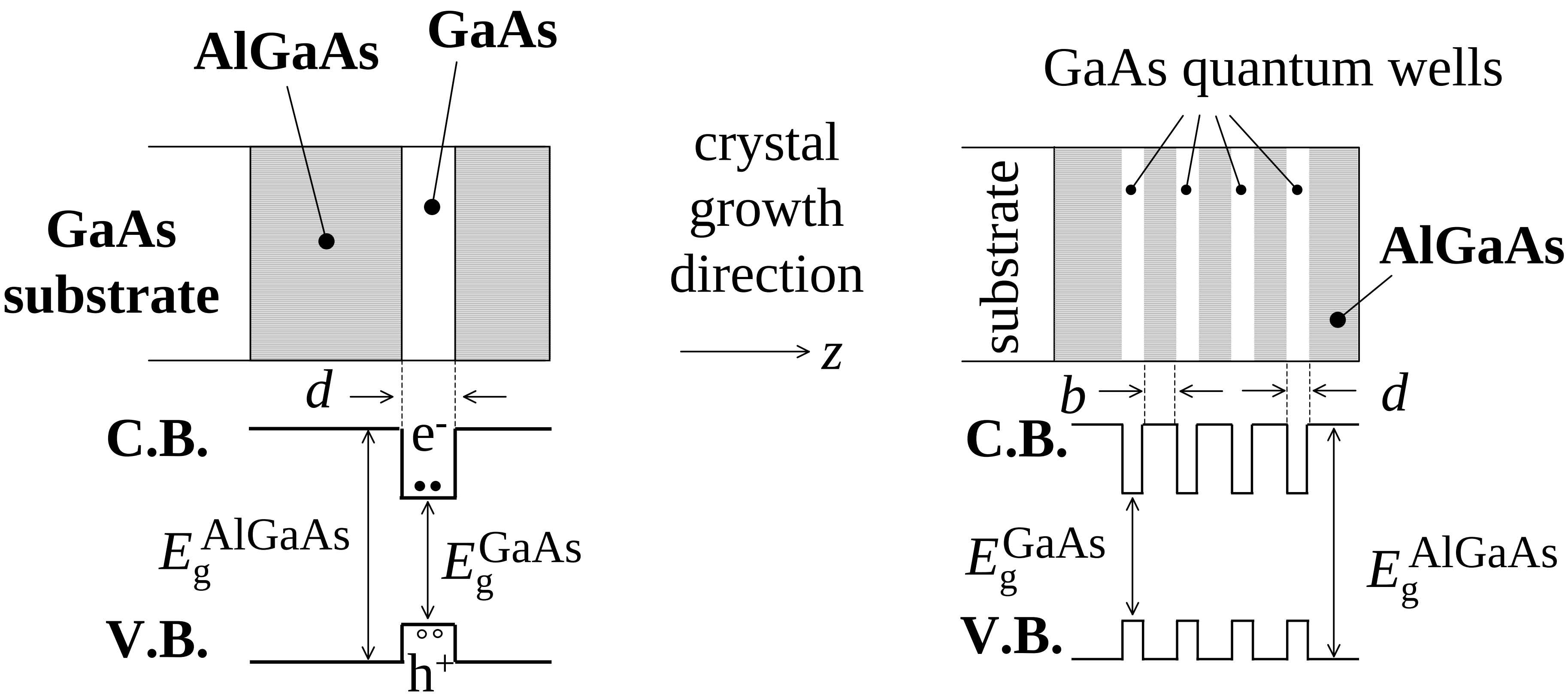
Fig. 6.1

Semiconductor quantum wells



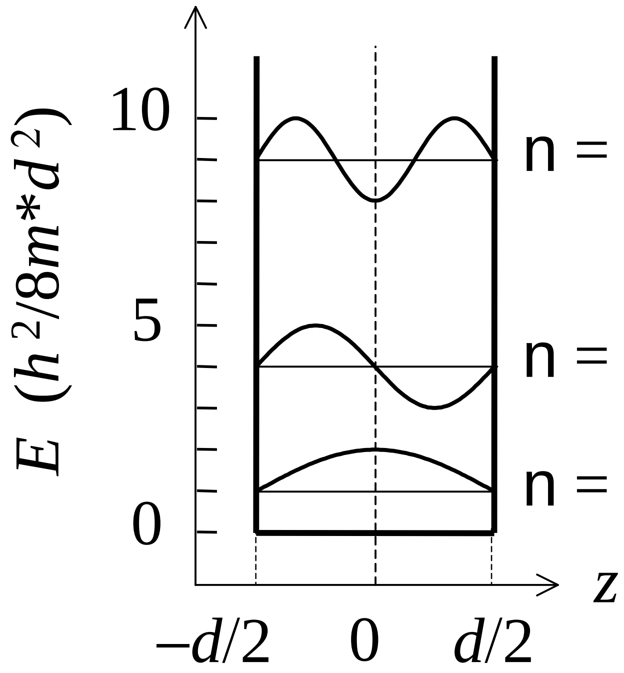
Single quantum well

MQW or superlattice

growth methods:
- Molecular beam epitaxy (MBE)
- Metal-organic chemical vapour deposition (MOCVD)

Infinite quantum well

Fig. 6.2

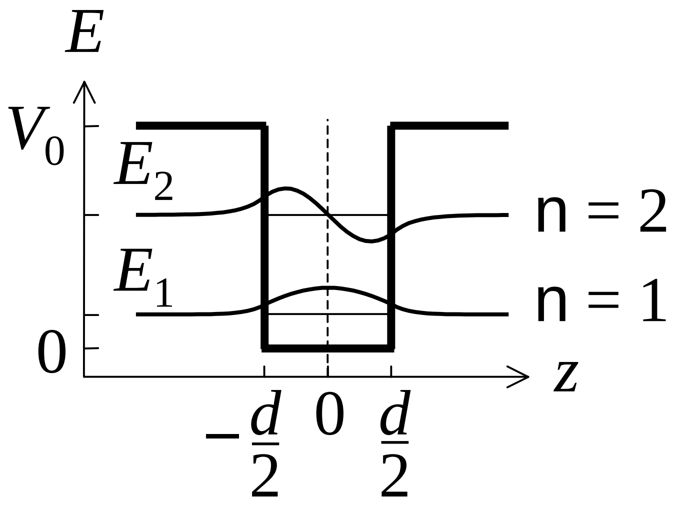


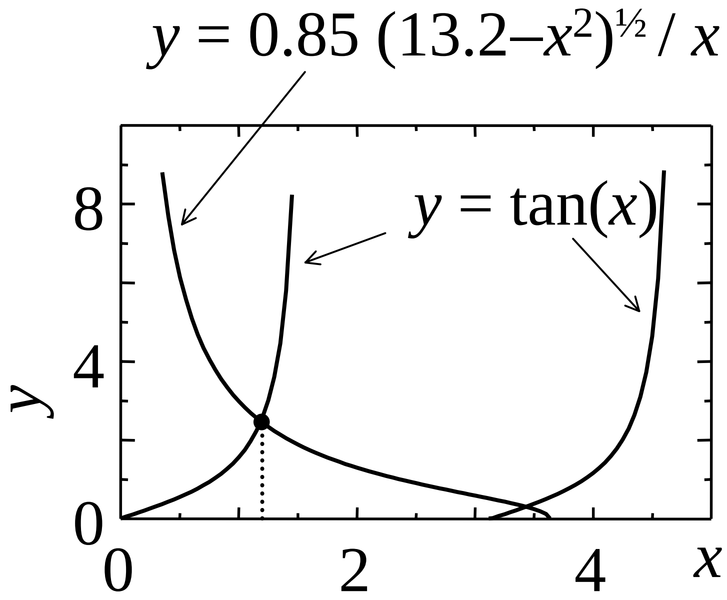
- $k_n = n\pi/d$
- $E_n = (\hbar^2\pi^2/2m^*d^2)\ n^2$
- $\psi_n = (2/d)^{1/2} \sin(k_n z + n\pi/2)$

- symmetry about $z = 0 \Rightarrow$ wave functions have definite **parity**
- ψ_n has (n–1) nodes
- E_n depends on m^*, hence heavy and light holes split

Figs 6.3–4

Finite quantum well





- Wave functions tunnel into the barrier
- wave function still identified by parity and number of nodes
- Confinement energy reduced compared to infinite well
- graphical solution to find E_n

<u>Example</u> : GaAs/AlGaAs

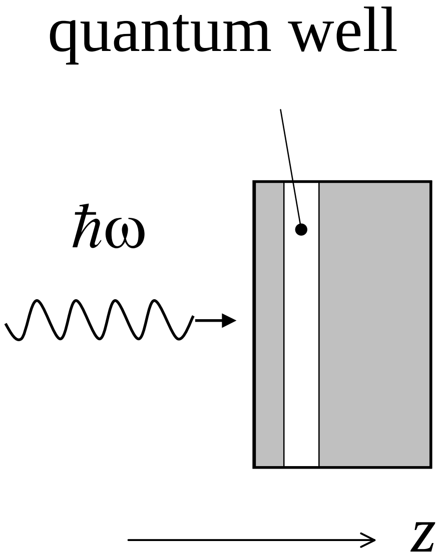
V_0 = 0.3 eV, d = 10 nm

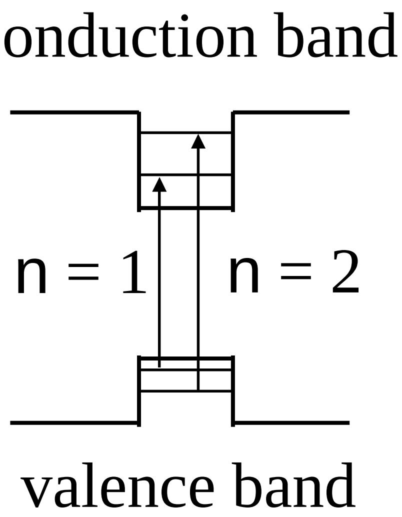
m_w*= 0.067m_e, m_b*= 0.092m_e

E_1 = 31.5 meV

c.f. infinite well: E_1 = 57 meV

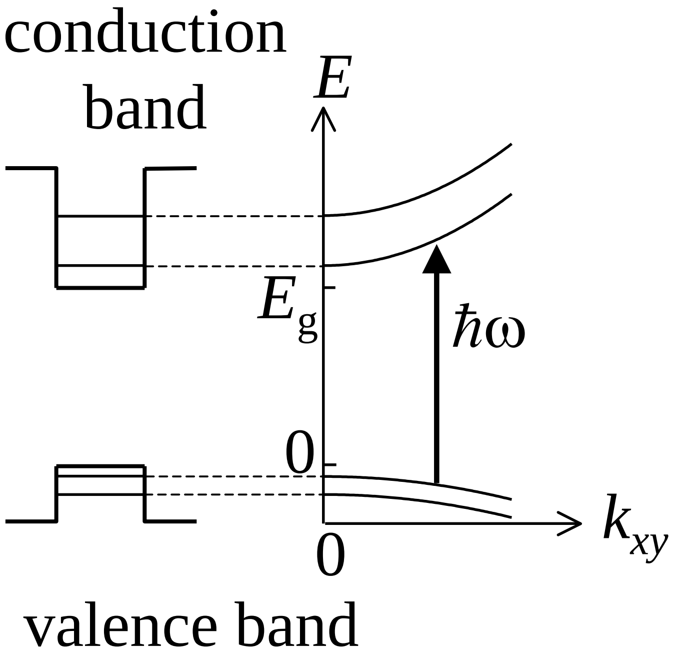
Optical transitions

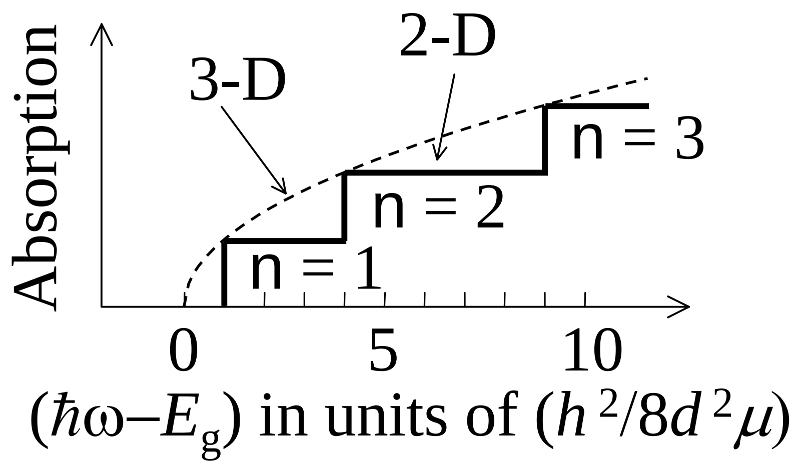




- Light polarized in *x*,*y* plane for normal incidence
- Parity selection rule: Δn = even number
- Infinite well selection rule: Δn = 0

2-D absorption



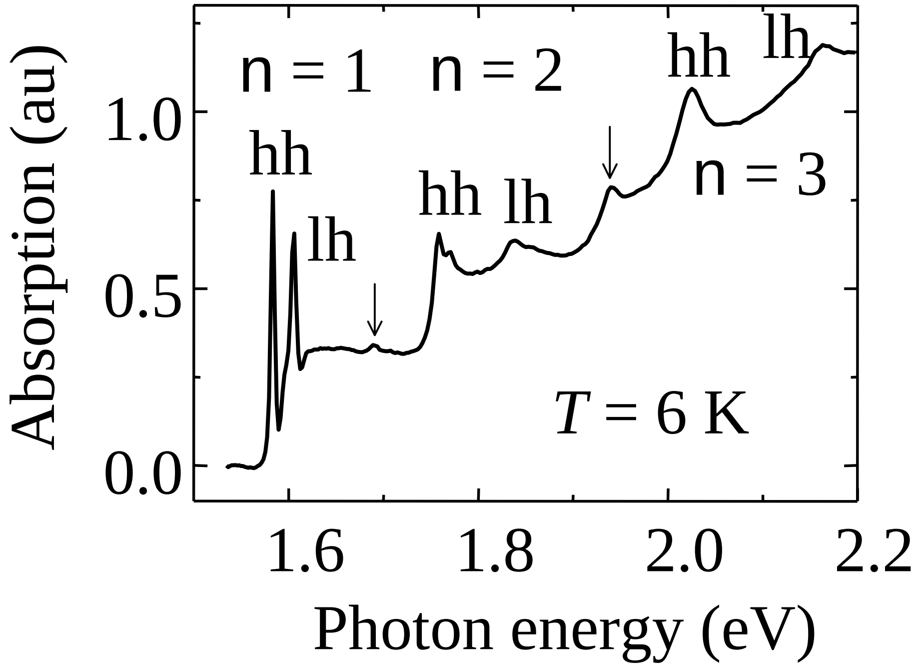


- Absorption $\propto$ density of states
- Density of states constant in 2-D: $g_{2D}(E) = m / \pi\hbar^2$
- Thresholds whenever $\hbar\omega$ exceeds $(E_g + E_{en} + E_{hn})$
- Band edge shifts to $(E_g + E_{e1} + E_{hh1})$

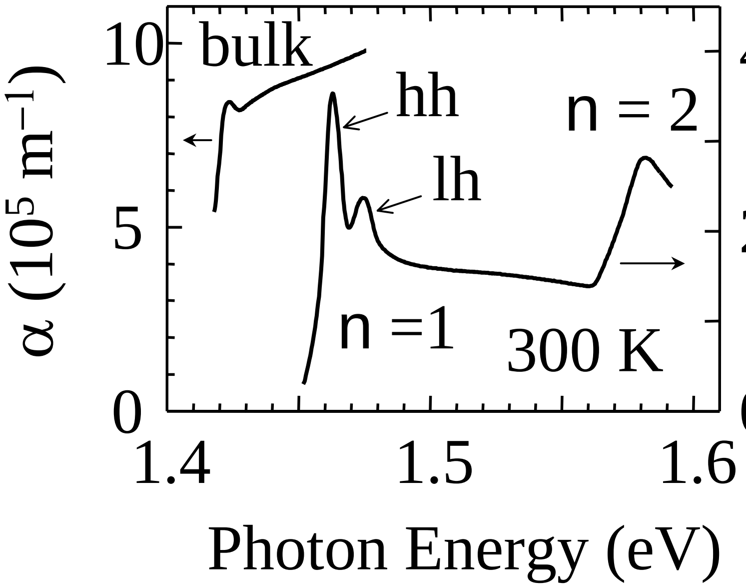
Figs 6.9–10

GaAs quantum wells

GaAs/AlAs MQW, d = 7.6 nm

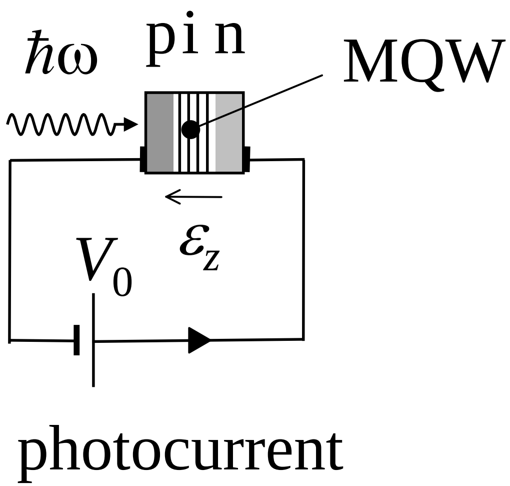


GaAs/AlGaAs MQW
d = 10 nm



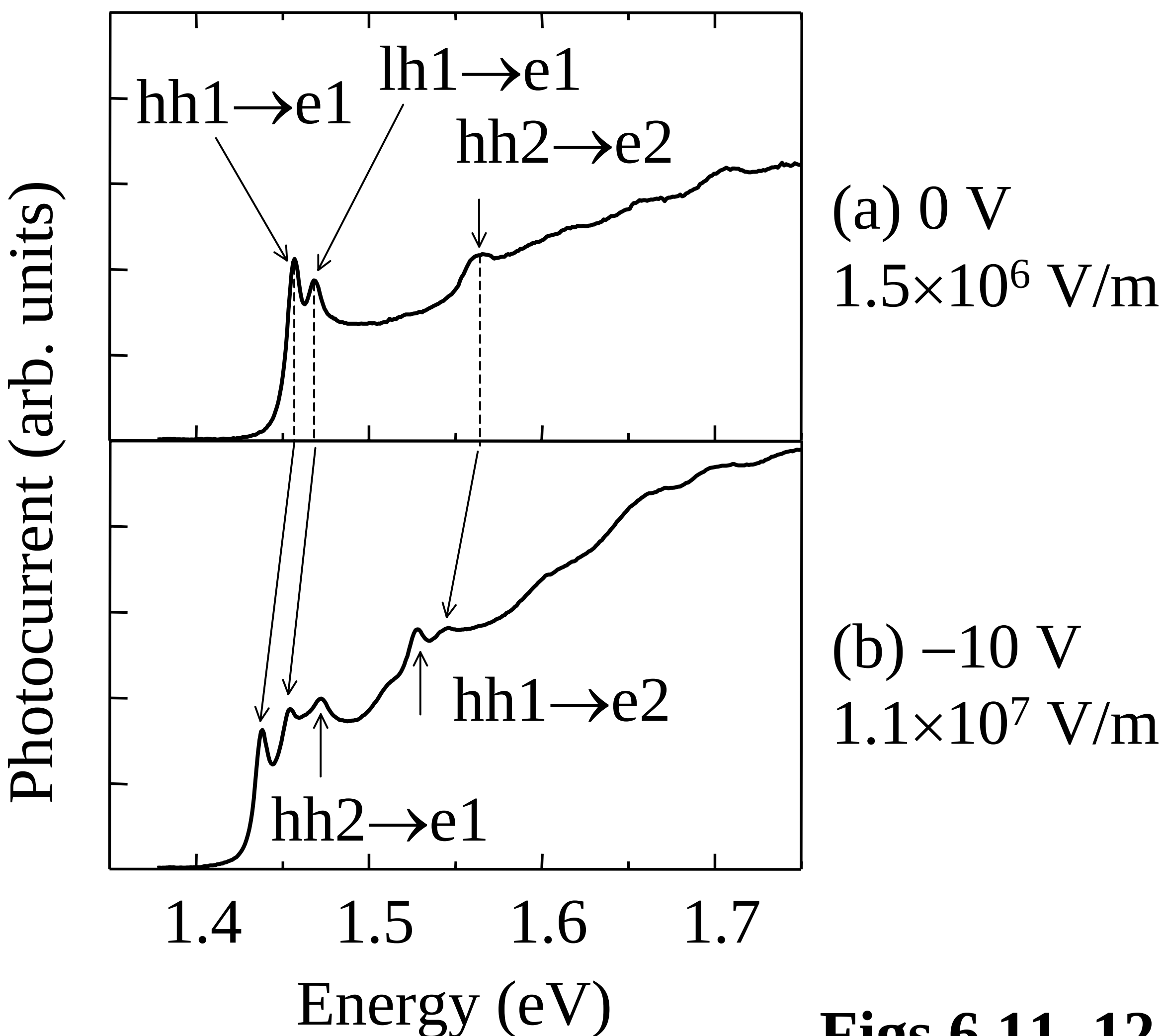
- Excitonic effects enhanced in quantum wells: strong at room temp
- Pure 2-D: $R_X^{2D} = 4 \times R_X^{3D}$
- Typical GaAs quantum well: R_X ~ 10 meV ~ 2.5 × R_X (bulk GaAs)
- Splitting of heavy and light hole transitions

The quantum confined Stark effect



- Red shift of excitons
- Excitons stable to high fields (c.f. Fig 4.5)
- Parity selection rule broken
- used to make modulators

GaAs MQW, d = 9.0 nm, 300 K

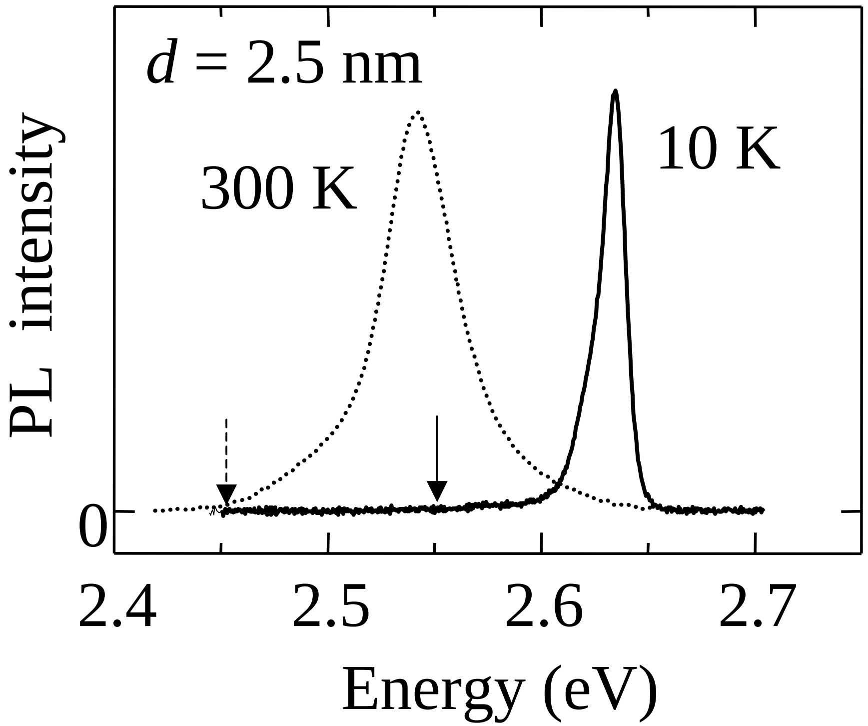


Figs 6.11–12

Figure 6.13

Emission spectrum

$Zn_{0.8}Cd_{0.2}Se/ZnSe$ quantum well



E_g = 2.55eV (10K)

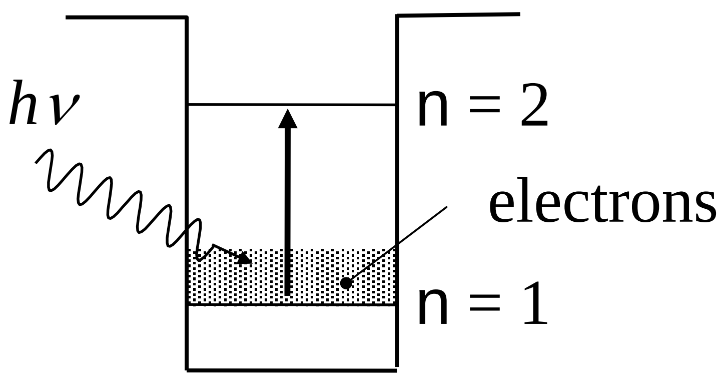
E_g = 2.45eV (300K)

- Emission energy shifted from E_g to ($E_g + E_{e1} + E_{hh1}$)
- Tune λ by changing *d*
- Brighter than bulk due to improved electron-hole overlap
- Used in laser diodes and LEDs

Figure 6.14

Intersubband transitions

n-type quantum well



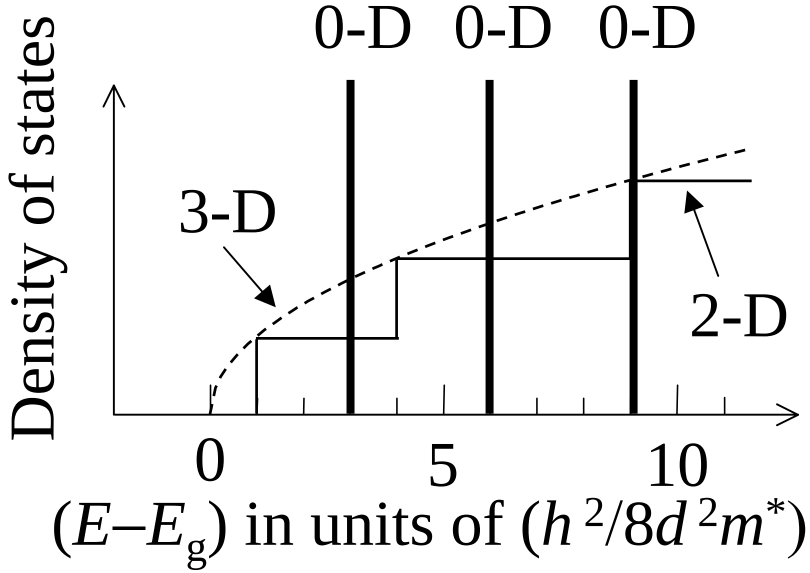
- Need *z* polarized light
- Parity selection rule:
  Δn = odd number

- Transition energy ~ 0.1 eV (~ 10 μm, infrared)
- Absorption used for infrared detectors
- Emission used for infrared lasers (Quantum cascade lasers)

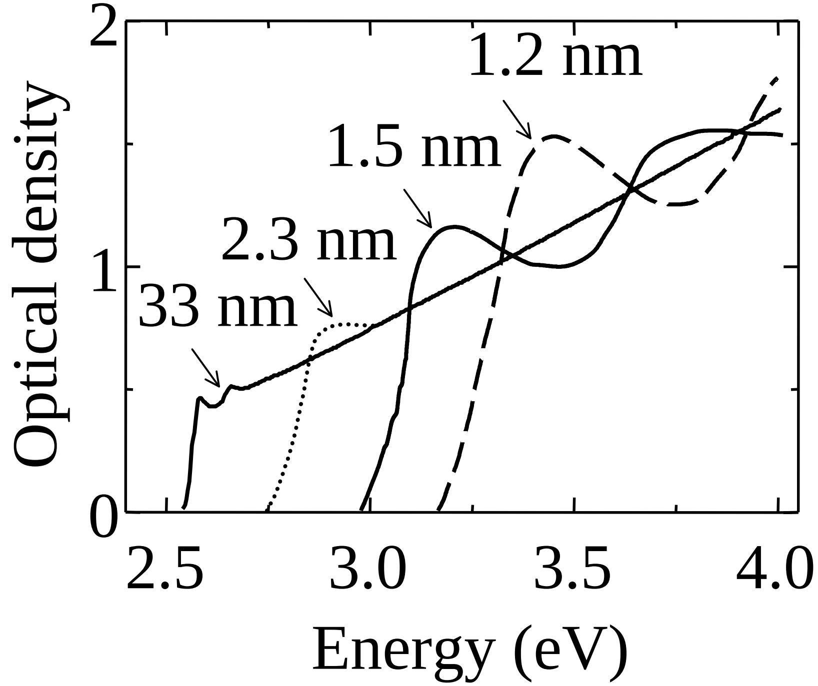
Quantum dots

Figs 6.15–16

Discrete atomic-like density of states



CdS quantum dots versus dot size d at 4.2K



Examples:

1. Semiconductor doped glass (Colour glass filters & stained glass)
2. Self-organized III-V quantum dots (eg InAs/GaAs)